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TOOLS FOR GROUND-BASED AND AERIAL SEEDING IN CANADA'S BOREAL FOREST

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Abstract

This report presents a review of seeders and other seeding devices used in reforestation, with an emphasis on seeding of coniferous species in the boreal forest. The functional components of direct-seeding systems and seeder mechanisms are described, and details on the equipment most commonly used in Canada are provided.

Introduction

Direct-seeding equipment for forest regeneration applications comprises a diverse range of implements. Although direct seeding has been used in Canada since the early 1900s (Waldron 1974), the technology is still in various stages of development.

Despite its advantages (flexibility, low cost, reduced personnel requirements and the possibility of regenerating large areas quickly to produce stands with natural root systems), direct seeding has not been widely used in Canada (Cayford 1974). The proportion of artificial regeneration attributed to direct seeding in Canada has actually declined from 33% in 1975 to less than 8% in 1992 (CCFM 1995). Only Ontario and Alberta were doing any significant amounts of direct seeding in 1992, accounting for 99% of the national effort. The small role played by direct seeding in regeneration programs probably stems from poor success rates in the 1960s and 1970s (Waldron 1974) combined with the public's perception of planting and the structure of government subsidies. Since then, a better understanding of the germination requirements of the major boreal tree species has been gained. Forest managers, ever on the search for cost-efficient, viable means of regeneration, are again looking closely at direct seeding.

Direct-seeding equipment can be employed during harvesting operations, simultaneously with site preparation, or following site preparation. Aerial seeders can be slung under helicopters or attached directly to helicopters and fixed-wing aircraft, and function mechanically. Seeders used for ground-based operations are all attached to their carrier, and operate either manually or mechanically. Regardless of their type, all seeders have certain functional features in common, such as a hopper, metering mechanism, seed-delivery system, and power source. A number of devices, treatments, and accessories have also been developed to increase reliability and enhance the chances of attaining the desired stocking.

The purpose of this report is to present the different methods of direct seeding and describe the types of tools that have been documented in the literature or in FERIC's silvicultural equipment databank. The report

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will thus provide a snapshot of the current state of the art in equipment. This report does not address the biological aspects of direct seeding. A manual on direct seeding being prepared by the Canadian Forestry Service (Sault Ste. Marie, Ontario) will provide a comprehensive examination of this issue. The present report also does not attempt to compare seeding tools, nor to exhaustively explore all available tools and their features; rather, it will highlight the tools most often used in Canada and others that demonstrate some potential in boreal forest applications. An upcoming FERIC report on the costs associated with direct-seeding systems will provide a guide to the choice of system and tools from an economic point of view.

Seeding Systems

Seeding systems are classified according to how the seed is sown and the scheduling of the sowing in relation to other forest management activities. Figure 1 illustrates the five seeding systems associated with artificial regeneration and a list of the seeders associated with each system.

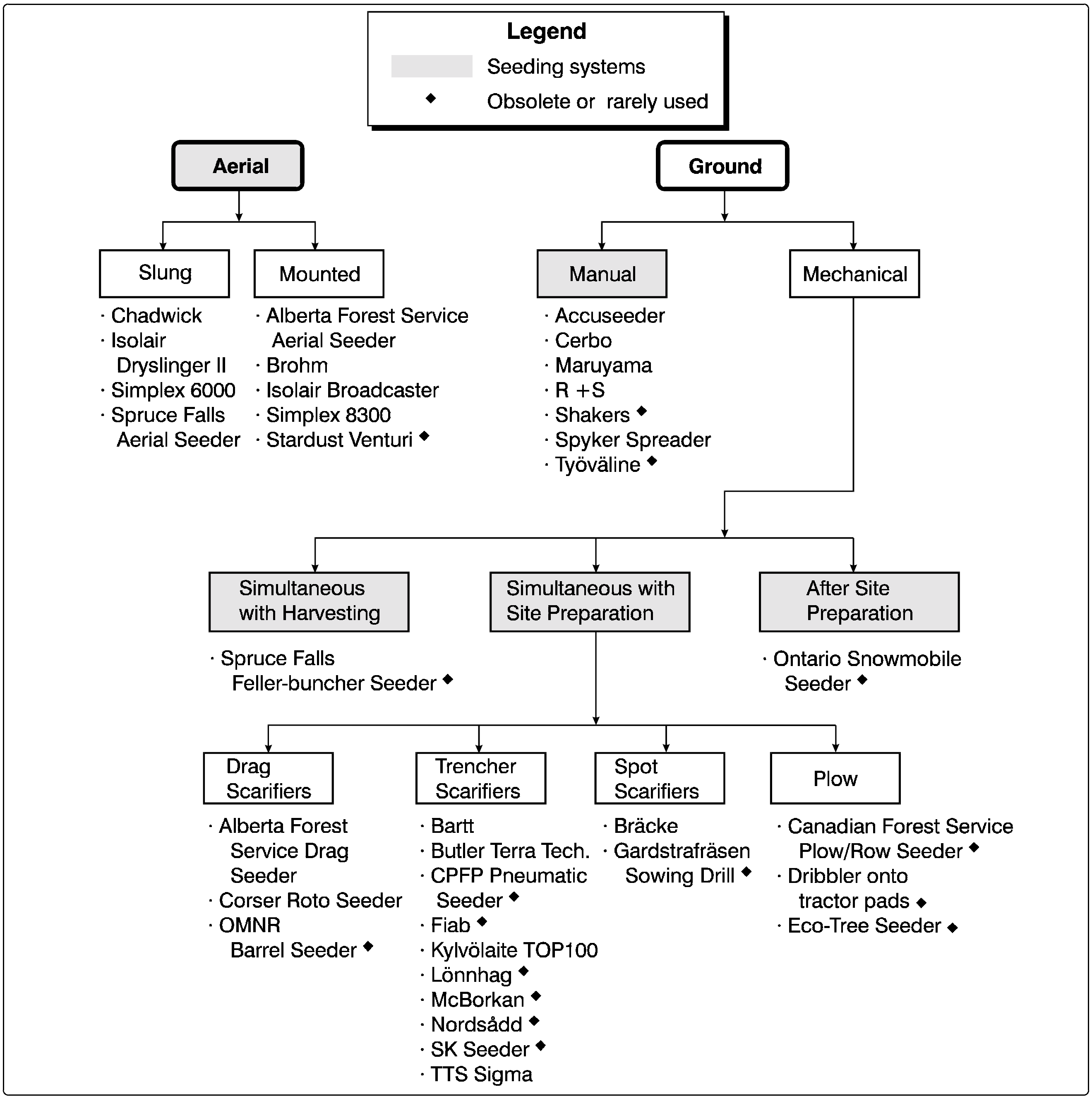


Figure 1. The five main seeding systems and their associated seeders.

Aerial Seeding

Aerial seeding involves broadcasting seed from either helicopters or fixed-wing aircraft (Figure 2). With helicopters, the seeder can either hang underneath on the cargo hook or be mounted on the body of the craft. Seeders on fixed-wing aircraft are always mounted on the underside. With aerial seeding, large areas can be seeded quickly, which facilitates sowing at the biologically optimum time. The application of seed is inexpensive due to economies of scale and low labor requirements, but uses large quantities of seed; this can significantly increase the overall cost. The success of this system depends on the site characteristics, the quality and quantity of the site preparation, and on a uniform seed distribution.

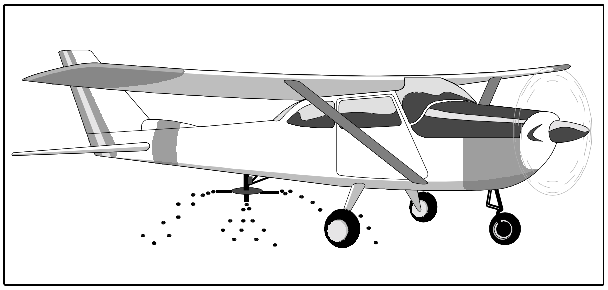


Figure 2. Aerial seeding with fixed-wing aircraft.

Ground-based Manual Seeding

Manual seeding can be accomplished by broadcasting the seed or by directing a measured quantity of seed to selected microsites (Figure 3). A number of seeders have been developed to perform these tasks. Broadcast manual seeding offers no advantage over aerial seeding other than being more applicable to small projects or areas. Spot seeding, on the other hand, uses very little seed, ensures that seeds fall only on proper microsites, and generally results in a more even stocking. With spot seeding, workers often create the microsite, thus eliminating the need for site preparation; however, the cost of this system is similar to that of planting seedlings, and workers must be more skilled in the selection of microsites. A number of devices, such as mini-shelters and peat disks, can be used to enhance germination and seedling survival.

Figure 3. Manual seeding using seed shelters.

Ground-based Mechanized Seeding—Simultaneous with Harvesting

This system involves a seeder (mounted on specific logging equipment) that releases seed at some point during harvesting, usually during the felling phase. Only one seeder of this type was found in the literature. The Spruce Falls seeder is mounted on a feller-buncher and releases black spruce seed at the base of the stump as each tree is cut (Figure 4). Seed release is triggered by the closing of the shearing jaw. This system has the advantages of being inexpensive and of using small quantities of seed. Since no site preparation is involved, the system can only be employed on a narrow range of sites (typically lowland black spruce with Sphagnum moss seedbeds). The seeder is currently not being used, and its success in providing enhanced stocking has not been examined.

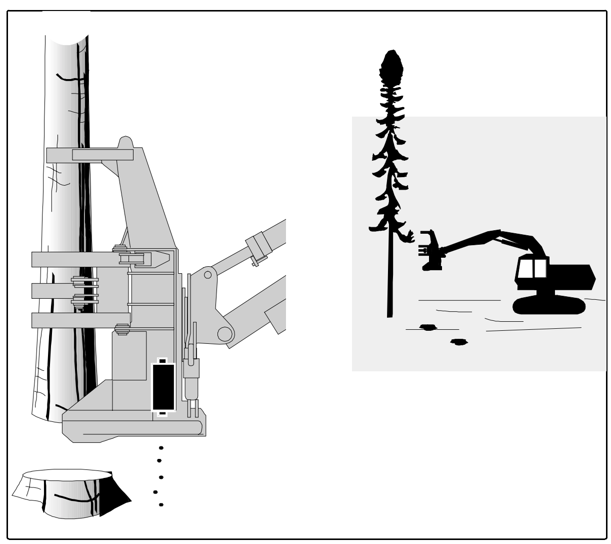


Figure 4. Mechanized ground-based seeding using a feller-buncher.

Ground-based Mechanized Seeding—Simultaneous with Site Preparation

By combining seeding with a site preparation operation, this system may represent the cheapest proven system of artificial seeding (Bryson and Van Damme 1994). Individual seeds or patches of seed are metered out with various degrees of accuracy and land on freshly prepared ground behind the scarifier (Figure 5). The system uses seed efficiently compared with broadcast sowing methods and can result in stands with stocking and density levels that are close to those prescribed. However, the quality of the site preparation and the placement of seed are critical to the operation's success. Biological constraints generally restrict this operation to the spring and autumn. Consequently, the number of hectares that can be seeded by this method in one year is limited. The system is generally used for jack pine and lodgepole pine, and its effectiveness remains unproven for other Canadian species. Seeders have been employed with almost all types of scarifiers, but have most commonly been used with disc trenchers, drags, and spot scarifiers.

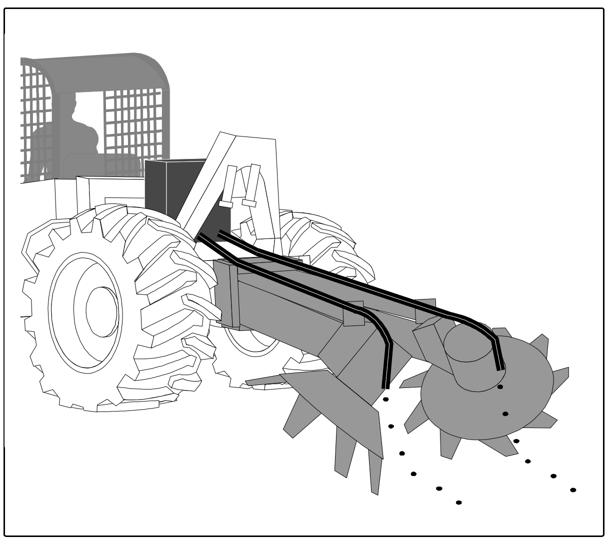


Figure 5. Ground-based mechanized seeding during site preparation with a disc trencher.

Ground-based Mechanized Seeding—After Site Preparation

Only one example of this system has been documented in the literature. A snowmobile-mounted seeder (Figure 6) was used sporadically to spread seed in winter on site-prepared sites in Ontario in the 1960s and 1970s, but is no longer used. Interest in this type of seeding declined because it offers few advantages over aerial seeding, is generally more expensive, and often provides a poorer seed-distribution pattern.

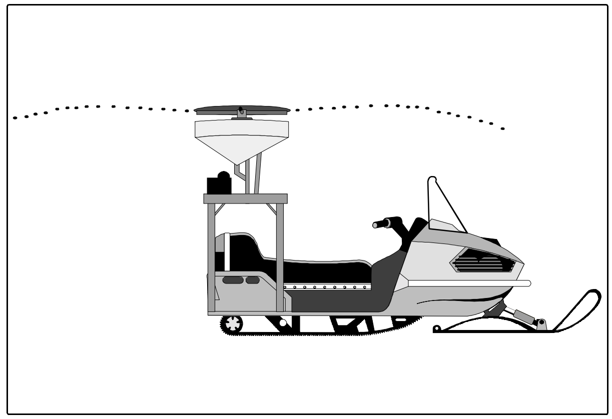


Figure 6. Ground-based mechanized seeding with a snowmobile after site preparation.

Seeder Principles

Regardless of the seeding system in which they are used, all seeders have some features in common. Each has four basic components (a seed hopper, a metering mechanism, a seed-delivery system, and a power source), and may have an optional monitor. The metering mechanism draws seed at a specified rate from the hopper and deposits it into the delivery system, which disperses the seed onto the treatment area. The optional monitor can record the passage of seed through the delivery system. The power source activates the meter either directly or by manipulating the hopper. Most delivery systems also require a power source.

Hoppers

Most hoppers are funnel-shaped and mounted on the seeder; gravity moves the seed toward the metering mechanism mounted on the bottom of the hopper. In a few cases, the hopper rotates to direct seeds towards the meter. Hoppers range in size from very large (approx. 2000 L for some aerial seeders) to as small as 40 mL for some manual seeders.

Metering Mechanisms

The seed of boreal conifers is small. The two most commonly sown species, jack pine and black spruce, may have 150 to 550 seeds per gram and 700 to 1450 seeds per gram, respectively. This represents a significant technical problem for all seeders, especially those used in aerial seeding. For example, a typical aircraft/seeder combination flying at 145 km/h with a swath width of 15 m will cover 604.2 m^2 per sec. At the commonly prescribed rate of 50 000 seeds/ha, the seeder must smoothly and uniformly dispense 3021 viable seed per second. To accomplish this, and even for the slower rates used in ground-based seeding, seeders must employ some form of metering mechanism.

The metering mechanism is the most critical component of any seeder because it is chiefly responsible for the density of seed dropped on the treatment area. It is also a significant potential source of seed damage (McNutt and Warrington 1989). Each seeder has its own particular mechanism for measuring out seed, but these mechanisms can be classified into six basic types (Figure 7).

The most common, Type 1 ("cell wheel"), involves a wheel with holes or concavities that fill with seed as they revolve vertically or horizontally past an opening in the hopper. As the holes, filled with seed, slide past the hopper's opening, the seed falls from the holes into the entrance of the delivery system. The metered rate is controlled by the number of holes, their size, and the speed at which the wheel rotates. One inherent problem with this type of meter is the potential to crush some of the seed as each cavity passes the edge of the hopper.

Type 2 ("vacuum disc") mechanisms are used in many agricultural and nursery seeders. The mechanism also uses the principle of a rotating wheel or disc, but the method by which seeds are picked up differs. In this case, a vacuum is applied to the outside of the disc as the holes in the disc pass by the opening on the hopper. The seeds are sucked to the holes, which are smaller than the seed, and held there until the wheel carries them past the hopper opening. Once outside the hopper, the vacuum releases and the seeds fall into the entrance of the delivery system. Some seeders use a cylinder rather than a wheel and apply the vacuum from inside the cylinder. This type of mechanism tends to be the most precise of all, and the metered rate is controlled in the same manner as with the Type 1 meters.

A Type 3 ("reciprocating rod") mechanism also uses a cavity-filling principle, but the wheel is replaced by a sliding rod. The rod's cavities collect seed from the hopper at one end of the rod's stroke and release seed into the delivery system at the other end. The meter rate is regulated by the number and size of the holes.

An auger incorporated into the bottom of the hopper removes seed from the hopper in a Type 4 ("auger") mechanism. To adjust the metering rate, augers with different pitches (i.e., slopes) or numbers of lands (i.e., the "vanes" of the auger) can be used, and the rotation speed of the auger can be controlled.

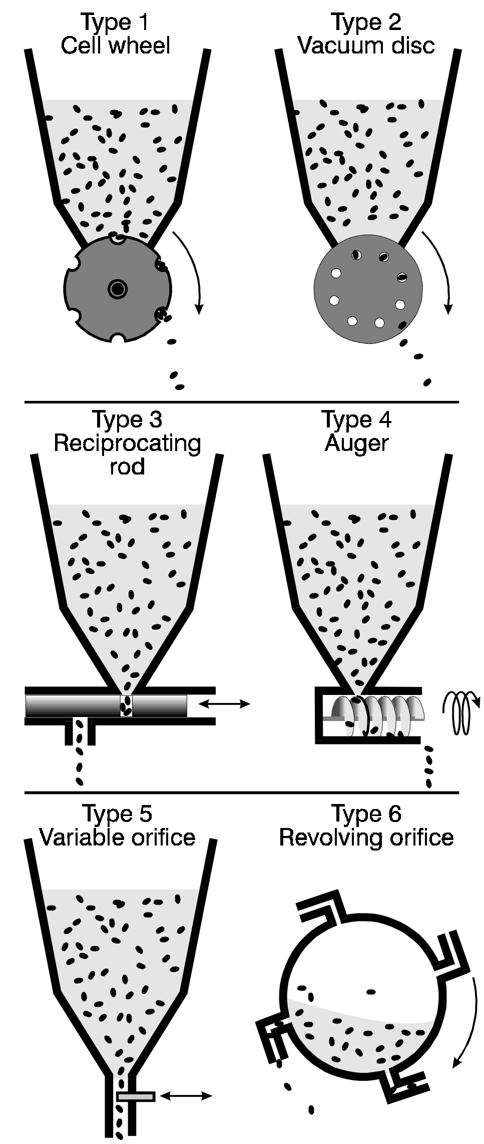


Figure 7. Six basic types of seed-metering mechanisms.

A simple sliding plate or valve controls the orifice size on the hopper in a Type 5 ("variable orifice") mechanism. The usual method of operation is to adjust the sliding plate to provide a fixed opening size that will provide a suitable continuous seed-flow rate. With this method, the delivery system and forward speed have more influence on the seed density in the treatment area than does the metered rate. Early versions of some seeders used this mechanism to intermittently drop small groups of seeds, but the continuous back and forth movement of the plate caused considerable seed damage.

Type 6 ("revolving orifice") mechanisms use a rocking motion or rotation of the hopper to direct the seed through an aperture to fill an elbow-shaped receptacle of a specific size. As the hopper continues to rotate, the seed falls out of a vent at the other end of the elbow and into the delivery system. The size and number of the receptacles, the rotation speed of the hopper, and the orientation of each receptacle's exit vent influence the metering rate. In some models, such as the barrel seeder, the elbows are absent and seed drops directly to the ground from the aperture.

Seed-delivery Systems

A seeder's delivery system is responsible for the dispersal of the metered seed onto the treatment area, and determines the pattern of seed distribution. Four typical kinds of systems are used with forestry seeders.

The simplest form of delivery is a straight drop from the meter under the influence of gravity, usually through a tube, onto a selected microsite. This delivery method is found almost exclusively in manual seeders.

Centrifugal delivery systems drop the metered seed onto the center of a rapidly spinning impeller that broadcasts the seed outward in an arc-like pattern. Impellers typically take the form of either a vaned, flat plate or a hub with projecting tubes, and rotate at a fixed speed. This delivery system is most common in aerial seeders, but is also seen in some manual seeders.

Pneumatic delivery systems use blowers, fans or compressed air to forcefully direct the seed towards favorable microsites. For this reason, these systems are often associated with ground-based mechanized seeding. They may also be used in aerial seeding to circumvent the undesirable effects of an aircraft's propeller wash on the seed distribution pattern.

The venturi delivery system, used exclusively with aircraft, uses a fan-shaped chute. Metered seeds fall into the narrow front end of the chute and are carried to the back by the air current created by the forward speed of the airplane. At the rear of the chute, vanes direct the seed outward in a fan-shaped pattern.

Power Sources

Most seeders require a power source to operate, since a force must be applied to operate the metering mechanism and the delivery system. These two components may be powered by the same source or separately.

The simplest case is that of a manual seeder powered by the operator, but other seeders use electric, hydraulic or gas motors. Gas motors are most often used when it is unsafe or impractical to use the power source of the prime mover, as in the case of a seeder slung under a helicopter. Hydraulic motors are a reliable power source for parts such as a centrifugal delivery system that require a constant speed. Electrical motors are particularly well adapted for metering mechanisms that control the metered rate by varying the speed of a wheel or auger. For consistent, reliable sowing rates, the prime mover must generate an adequate electrical or hydraulic output under all operating conditions (Dominy 1991, 1993).

Some seeders use a variety of mechanical linkages to moving parts on the prime mover or scarifier. When this linkage occurs between a meter and a part associated with the forward speed, such as the mattock wheel on a Bräcke, it is possible to achieve a very close association between the area covered and the amount of seed dispersed.

Monitoring Systems

Most forestry seeders operating in Canada do not use seed-counting devices to ensure a consistent sowing rate. Instead, monitoring usually involves spot checks that use seed traps laid out beforehand (Cameron and Foreman 1995) or timed collections from the delivery system (Davidson 1992).

Seeders that produce flow rates of 1600 or more seeds per second, such as those used in aerial applications, generally monitor the declining level of seed in the hopper to assure the operator that seed is continuing to flow. Flow rates are calibrated beforehand and are assumed to remain constant throughout.

Seeders referred to as "precision seeders" dispense such low quantities of seed onto selected microsites that they provide little margin of error against a possible shortfall in stocking. For these seeders, it is important to ensure that the prescribed sowing rate is being met. To date, however, attempts to attach seed-counting devices to these seeders have not been very satisfactory because the monitors tend to be unreliable. However, FERIC has recently used an infrared sensor successfully to count seed from a Bräcke seeder.

Enhancements

A number of devices can be employed to increase the efficiency of seeders or enhance the chances of germination and seedling survival. One technique often used in connection with manual spot seeders is the use of seed shelters, which have been shown to increase survival and growth on certain site types (Adams 1995a; Adams and Henderson 1994). Shelters are typically open-ended cones made of biodegradable or photodegradable material that are placed over the seed to ameliorate the microclimate and protect the seed from predators (Figure 8). A preseeded shelter cone developed by FERIC and Spencer Lemaire Industries eliminates the need for a seeding tool, and has recently become commercially available. Similar preseeded shelter cones are made by Shepherd Thermoforming and Packaging Inc. (Brampton, Ont.) and KBM Forestry Consultants Ltd. (Thunder Bay, Ont.).

Figure 8. A shelter cone made of a photodegradable material.

Increased germination rates and extended sowing seasons have been noted for direct-seeded jack pine when the mineral soil exposed by mechanical site preparation has been compacted (Van Damme et al. 1988). Compaction can be achieved as a result of natural weathering of the microsite, and this often occurs when seeding follows a few months after the scarification; however, when seeding occurs simultaneously with site preparation, compaction should be done concurrently. To accomplish this, rollers or wheels have been attached behind the site preparation equipment (Figure 9), but these implements have not proven to be operationally efficient.

Figure 9. Soil-compaction wheels with seed-delivery tubes mounted behind a Bräcke B-290 mounder. (Photo credit: Anders Hildeman, SCA Skog)

Pelletizing seed involves the application of solid, inert materials to a single seed, in sufficient quantity to embed the seed in a relatively uniform spherical shape (Mike Adams, Canadian Forest Service, personal communication). Pelletized seed can improve the effectiveness of many seeders (Adams 1995b) by improving the seed flow through hoppers, meters, and delivery systems. It also improves the ballistic properties of seed used in broadcast aerial seeding and improves the accuracy of most meters. Pelletizing can also facilitate the simultaneous seeding of more than one type of seed from the same hopper. Seeds of different species have different sizes and weights, and will separate out in the hopper as a result of vibration, but seed pelletized to have the same size and weight will not have this problem. As a result, a more even species distribution can be obtained.

Sowing seed glued to the surface of a peat pellet is a relatively new technique that shows some promise, but the technique has not yet been rigorously tested. Jiffy Products Ltd. (Shippegan, N.B.) manufactures the pellets.

Technical Specifications

Tables 1 through 4 provide details on the most commonly used seeders in Canada, as well as others that illustrate the range of types available. Further information on all the seeders in Figure 1 can be obtained from the FERIC Silvicultural Equipment Databank (Lirette 1991). The addresses of manufacturers and distributors of direct-seeding tools are listed on page 14. Some seeders are under development or are no longer commercially manufactured, in which case a user or a contact agency is provided instead.

Table 1. Aerial seeders slung from helicopters

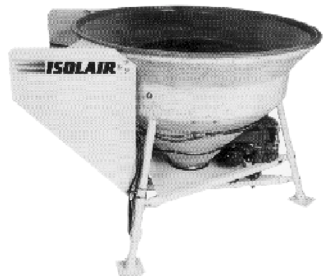
	Isolair Dryslinger II	Spruce Falls Aerial Seeder
		
Model(s)	2600 series (see "additional information", below)	n.a.
Manufacturer	Isolair	Spruce Falls Inc.
Distributors	Isolair	Spruce Falls Inc.
Purchase price	US$6495 - US$10 995	n.a.
Hopper size (L)	450 - 1980	approx. 50
Metering		
Mechanism type	Type 5 (variable orifice)	Type 1 (cell wheel)
Method of adjustment	hydraulic adjustment of opening size	rotation speed of disk
Seed delivery system	centrifugal impeller (an open plate with blades)	centrifugal slinger with three rubber tubes
Power source	gas or hydraulic motor	gas generator and electric motor
Enhancements/accessories	• low-flow orifice and gate • cockpit-mounted level display • bucket cover • acre meter/timer • quick-load bag and integrated weighing cell for shorter loading time	n.a.
Additional information	12 models, distinguished by hopper size and power: 2600-16(G)(H) - 16 ft^3 2600-20(G)(H) - 20 ft^3 2600-25(G)(H) - 25 ft^3 2600-45(G)(H) - 45 ft^3 2600-60(G)(H) - 60 ft^3 2600-70(G)(H) - 70 ft^3	• slung under a Bell Long Ranger helicopter • not commercially manufactured
Similar seeders	• Chadwick (user: Frontier Helicopters) • Simplex 6000 series	None
Photo credit	Isolair	Spruce Falls Inc.

Table 2. Aerial seeders mounted directly on helicopters and on fixed-wing aircraft

	Alberta Forest Service Aerial Seeder[a]	Isolair Broadcaster[a]	Brohm[b]
			
Model(s)	n.a.	• 4500-206 for Bell 206 • 4500-47 for Bell 47	MK 3
Manufacturer	plans available from Alberta Environmental Protection for C$50	Isolair	no longer manufactured
Distributors	None	Isolair	General Airspray Ltd.
Purchase price	approx. manufacturing cost = C$20 000	US$14 955	n.a.
Hopper size (L)	approx. 510	566	approx. 225 (80 kg)
Metering			
Mechanism type	Type 1 (cell wheel)	Types 4 and 5 combined (auger and variable orifice)	Type 4 (auger)
Method of adjustment	adjust the size of holes in a rotating drum	adjust flow gate	speed of auger, number of lands on auger
Seed delivery system	centrifugal	pneumatic	centrifugal slinger with four plastic tubes
Power source	electric motor	• 4500-206: electric motor • 4500-47: hydraulic motor	electric motor
Enhancements/accessories	n.a.	100-amp generator kit required for 4500-47 model	None
Additional information	• each unit and installation must receive aeronautical certification • used primarily with a Bell 206 • not commercially manufactured (blueprints available from Alberta Environmental Protection)	n.a.	• originally built for and used on Bell G-2 and G-4 helicopters but modified for fixed-wing aircraft and now normally used on a Piper PA-18A Super Cub • Fleming et al. (1985) • Foreman and Riley (1979) • Smith (1980)
Similar seeders	None	Simplex 8300 series	None
Photo credit	M. McLaughlan	Isolair	M. Ryans

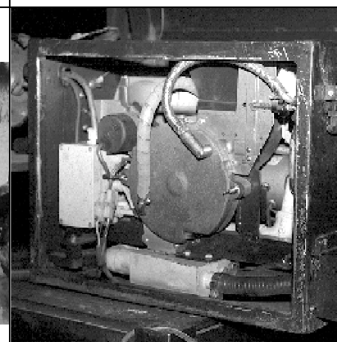
[a] Helicopter-mounted.

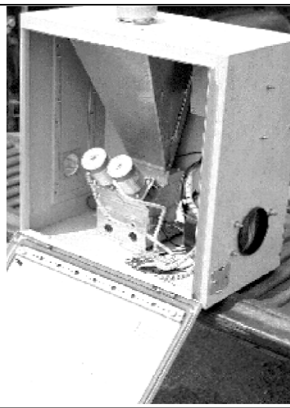
[b] Mounted on fixed-wing aircraft.

Table 3. Manual seeders

	Maruyama Granule Spreader	**Accuseeder**
		
Model(s)	MG-10	n.a.
Manufacturer	Maruyama USA	KBM Forestry Consultants Ltd.
Distributors	Terra Tech Inc.	KBM Forestry Consultants Ltd.
Purchase price	US$104	C$250
Hopper size (L)	11	0.04
Metering		
Mechanism type	Type 5 (variable orifice)	Type 1 (cell wheel)
Method of adjustment	manual adjustment of sliding flow gate	wheels with different-sized cups
Seed delivery system	centrifugal	gravity drop
Enhancements/accessories	n.a.	to be used with Cerkon shelter cones
Additional information	• tank agitator keeps the seed from clogging • covers up to 18 feet • can also be used for dry chemicals (e.g., fertilizer)	n.a.
Similar seeders	Spyker Spreader Model 75	Cerbo Seeder
Photo credit	M. McLaughlan	J. Lirette

Table 4. Seeders for seeding simultaneous with site preparation

	Alberta Forest Service Drag Seeder	**Bartt Seeder**	**Butler Seeder**
			
Model(s)	n.a.	MK V	n.a.
Manufacturer	Craig Forest Products Ltd.	Bartt Forestry Equipment Ltd.	Terra Technology Ltd.
Distributors	Craig Forest Products Ltd.	KBM Forestry Consultants Ltd.	Terra Technology Ltd.
Purchase price	C$24 000 - $30 000	C$14 000	C$6000
Hopper size (L)	approx. 20	approx. 0.75	One hopper @ 4.8 and two hoppers @ 0.46
Metering			
Mechanism type	Type 1 (cell wheel)	Type 2 (vacuum disc)	Type 6 (revolving orifice)
Method of adjustment	change size and number of holes in a rotating cylinder	discs with different sizes and numbers of holes	change size and angle of elbow
Seed delivery system	gravity drop	pneumatic	pneumatic
Power source	mechanical linkages to seeder's wheels	electric motor	electric motor
Enhancements/accessories	optional seed-count sensor with radio modem link to a computer in the prime mover	optional seed monitor on the delivery system	fiber-optic or laser seed monitors are optional (approx. C$4000)
Additional information	• used primarily behind two rows of shark-finned barrels • can be used behind other types of scarifier	• used with disc-trencher style of scarifier • Dominy (1991, 1993) • Davidson (1992) • Corbett (1992)	• can seed two species alternately or simultaneously by using separate hoppers • used with disc-trencher style of scarifier
Photo credit	R. Reynolds	R. Reynolds	R. Reynolds

TTS Sigma Seeder	**Bräcke Spot Seeder**	**Barrel Seeder**
		
n.a. TTS Forestry Oy Hakmet Ltd. US$9000	n.a. Robur Maskin AB KBM Forestry Consultants Ltd. C$7500 per frame	n.a. None None approx. C$2000 - $3000
approx. 3 Type 4 (auger) auger speed or auger configuration pneumatic electric motor	1.5 Type 3 (reciprocating rod) rods with different sizes and numbers of holes pneumatic mechanical linkages to scarifier's mattock wheel	approx. 12 Type 6 (revolving orifice) number and size of orifices gravity drop passive turning of barrel as it is pulled (caused by spiral fins)
n.a.	optional packing wheels	n.a.
• used with disc-trencher style of scarifier • Davidson (1992) FERIC	• used exclusively with Bräcke scarifier • metering rod can take up to six seed cavities • Van Damme (1992) • Bryson and Van Damme (1994) • McNutt (1992) • Sidders (1993) M. Ryans	• attached by chain and clevises behind a row of shark-finned barrels • Smith (1980) • Lees and Higgs (1991) M. Ryans

Manufacturers, Distributors and Users of Seeding Devices

Alberta Environmental Protection
Land and Forest Service Division
6th Floor, Bramalea Bldg.
9920 - 108 Street
Edmonton, Alberta T5K 2M4

Bartt Forestry Equipment Ltd.
148 Bowes Road
Concord, Ontario L4K 1J6
Tel.: (905) 660-7623
Fax: (905) 669-9589

Canadian Forestry Equipment Ltd.
17309 - 107 Avenue
Edmonton, Alberta T5S 1E5
Tel.: (403) 484-6687 or
1-800-661-7959
Fax: (403) 484-6763

Craig Forest Products Ltd.
RR#2
Morinville, Alberta T8R 1P5
Tel.: (403) 939-4584
Fax: (403) 939-2557

Frontier Helicopters
P.O. Box 220
Abbotsford, B.C. V2S 4N9
Tel.: (604) 855-1190
Fax: (604) 855-1189

General Airspray Ltd.
RR#1
Lucan, Ontario N0M 2J0
Tel.: (519) 227-4091

Hakmet Ltd.
881 Harwood Blvd.
P.O. Box 248
Dorion, Quebec J7V 7J5
Tel.: (514) 455-6101
Fax: (514) 455-1890

Isolair
20490 E. Aschoff Rd.
Rhododendron, Oregon
97049 USA
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Fax: (503) 622-4274

Jiffy Products Ltd.
P.O. Box 360
Shippegan, N.B. E0B 2P0
Tel.: (506) 336-2284
Fax: (506) 336-9609

KBM Forestry Consultants Ltd.
349 Mooney Avenue
Thunder Bay, Ontario P7B 5L5
Tel.: (807) 344-0811 or
1-800-465-3001
Fax: (807) 345-3440

Koinonia Corporation
4806 - 17th Avenue
Edson, Alberta T7E 1G5
Tel.: (403) 723-6957
Fax: (403) 723-5222

Maruyama USA
P.O. Box 2167
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Fax: +46-693-101 09

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97230 USA
Tel.: (503) 257-3511
Fax: (503) 257-8556

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References

Adams, M.J. 1995a. Seed shelters improve black spruce establishment on upland cutovers. Nat. Resour. Can., Can. For. Serv., Sault Ste Marie, Ont. Frontline Tech. Note No. 47. 4 p.

Adams. M.J. 1995b. Seed treatments have potential for direct seeding. Nat. Resour. Can., Can. For. Serv., Sault Ste Marie, Ont. Frontline Tech. Note No. 34. 4 p.

Adams, M.J.; Henderson, G.S. 1994. Plastic and peat seed shelters improve stocking. Nat. Resour. Can., Can. For. Serv., Sault Ste Marie, Ont. Frontline Tech. Note No. 16. 4 p.

Bryson, T.; Van Damme, L. 1994. A comparison of five common artificial regeneration methods for jack pine in northwestern Ontario. Ont. Min. Nat. Resour., Northwest Region Science and Technology, Thunder Bay, Ont. Tech. Rep. No. 80. 17 p.

Cameron, D.A.; Foreman, F.F. 1995. Seed trapping to monitor operational aerial seeding. Nat. Resour. Can., Can. For. Serv., Sault Ste. Marie, Ont. Frontline Tech. Note 43. 4 p.

Cayford, J.H. 1974. Ed., Direct seeding symposium, Timmins, Ontario, 11-13 September, 1973. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. No. 1339. 178 p.

CCFM. 1995. REGEN: a program for reporting on forest regeneration. Can. Counc. For. Min., National Forestry Database Program, Ottawa, Ont. 167 p.

Corbett, P. 1992. Bartt precision seeder trial. Ont. Min. Nat. Resour., Northwestern Ont. For. Technol. Devel. Unit, Thunder Bay, Ont. TN-12. 4 p.

Davidson, P. 1992. Bartt Mark IV and TTS Sigma precision seeders. Ont. Min. Nat Resour., Northwestern Ont. For. Technol. Devel. Unit, Thunder Bay, Ont. TN-11. 12 p.

Dominy, S.W.J. 1991. Evaluation of the Bartt MKIV direct seeder. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Tech. Note TN-170. 6 p.

Dominy, S.W.J. 1993. The Bartt MKIV seeder—follow-up evaluation. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Field Note Silviculture-51. 2 p.

Fleming, R.L.; Foreman, F.F.; Regnière, J. 1985. Black spruce seed distribution with the Brohm seeder/Piper PA-18A aircraft combination. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-370. 23 p.

Foreman, F.F.; Riley, L.F. 1979. Black spruce seed distribution using the Brohm seeder/Piper PA-18A aircraft combination. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-294.

Lees, J.C.; Higgs, B.J. 1991. Enrichment of hardwood regeneration on contemporary clear-cuts by direct seeding of birch. Pages E1-E5 *in*: Preprint Volume, Woodlands Section, 72nd Annual Meeting, 1991. Can. Pulp and Paper Assoc., Montreal, Que.

Lirette, J. 1991. FERIC silvicultural equipment databank. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Field Note Silviculture-33. 2 p.

McNutt, J.W. 1992. Ground speed: its influence on direct-seeding jack pine with the Bräcke scarifier. Lakehead University, School of Forestry, Thunder Bay, Ont. 107 p.

McNutt, J.W.; Warrington, S.R. 1989. Calibration accuracy and seed damage testing of seeders used in forestry. Lakehead University, School of Forestry, Thunder Bay, Ont. 55 p.

Sidders, R.G. 1993. Bräcke seeding rate trials: fifth year results. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont. Tech. Rep. 72. 19 p.

Smith, C.R. 1980. Silviculture equipment reference catalogue for northern Ontario. Ont. Min. Nat. Resour., Toronto, Ont.

Van Damme, L. 1992. Microsite soil compaction enhances establishment of direct-seeded jack pine in northwestern Ontario. Northern J. Appl. For. 9(3):107-112.

Van Damme, L.; Buse, L.; Warrington, S. 1988. The effect of microsite compaction on direct seeding success of jack pine and black spruce in northwestern Ontario. Prepared by KBM Forestry Consultants Inc. for Can. For. Serv., Sault Ste. Marie, Ont., under the Canada-Ontario Forest Resources Development Agreement, Project No. 33010. 36 p.

Waldron, R.M. 1974. Direct seeding in Canada 1900-1972. Pages 11-27 *in*: Cayford, J.H., Ed., Direct seeding symposium, Timmins, Ontario, 11-13 September, 1973. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. No. 1339. 178 p.

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